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Jung et al.

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(54) **RECYCLING UNIT AND SUBSTRATE
TREATING APPARATUS**

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H01L 21/00 (2006.01)

(52) **U.S. Cl.**
CPC **H01L 21/00** (2013.01)

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3/26; B01D 53/22; C01B 31/20; A01N 25/00;
A01N 59/04

USPC 34/570, 77.78, 79, 201, 218; 202/153,
202/161; 424/405, 84, 717

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,757,427 A * 9/1973 Wilkinson B05D 3/04
34/479
5,940,985 A * 8/1999 Kamikawa H01L 21/02052
257/E21.228
7,437,834 B2 * 10/2008 Nakatsukasa H01L 21/02052
34/381
8,196,312 B2 * 6/2012 Taguchi B41C 1/1083
118/65

(Continued)

FOREIGN PATENT DOCUMENTS

KR 2007-0012560 A 1/2007
KR 101155612 B1 6/2012

(Continued)

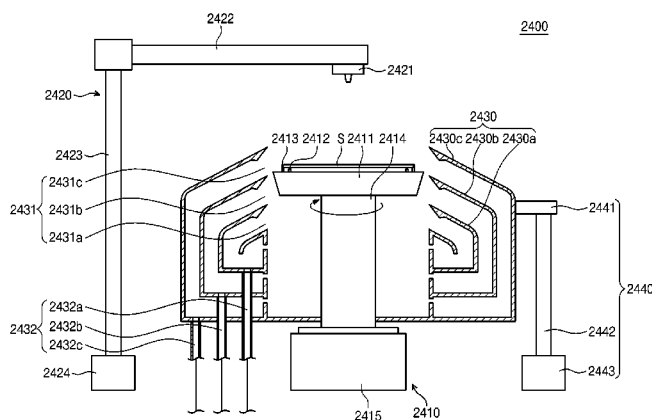
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(57) **ABSTRACT**

The substrate treating apparatus includes a drying chamber in which an organic solvent remaining on a substrate is dissolved by using a fluid, and a recycling unit including a separator for separating the organic solvent from the fluid discharged from the drying chamber to recycle the fluid. The separator includes a distiller in which a fluid containing an organic solvent having a first concentration is introduced, a heating unit heating a fluid containing an organic solvent having a second concentration discharged from the distiller, and supplying an evaporated fluid containing an organic solvent having a third concentration into the distiller, and a condensation unit liquefying a fluid containing an organic solvent having a fourth concentration discharged from the distiller. The organic solvent has the second concentration, the first concentration, the third concentration, and the fourth concentration which are successively lowered in concentration.

33 Claims, 15 Drawing Sheets



(56)

References Cited

FOREIGN PATENT DOCUMENTS

U.S. PATENT DOCUMENTS

8,904,668 B2 * 12/2014 Priebe F26B 3/22
 101/450.1
 2014/0290093 A1 * 10/2014 Jung H01L 21/00
 34/570

KR 20130007396 A 1/2013
 KR 20130007397 A 1/2013
 KR 20130014311 A 2/2013
 KR 20140120238 A * 10/2014

* cited by examiner

FIG. 1

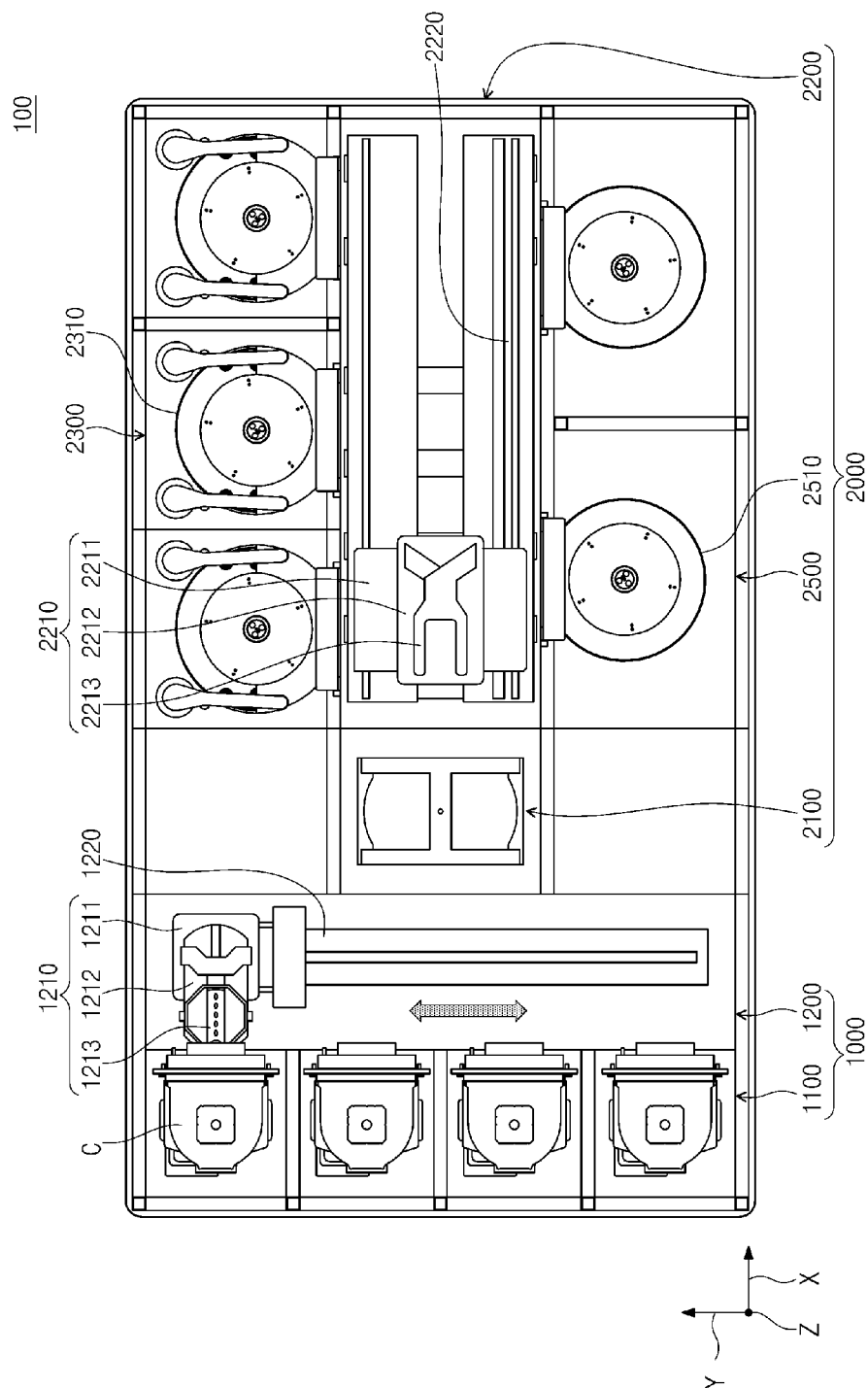


FIG. 2

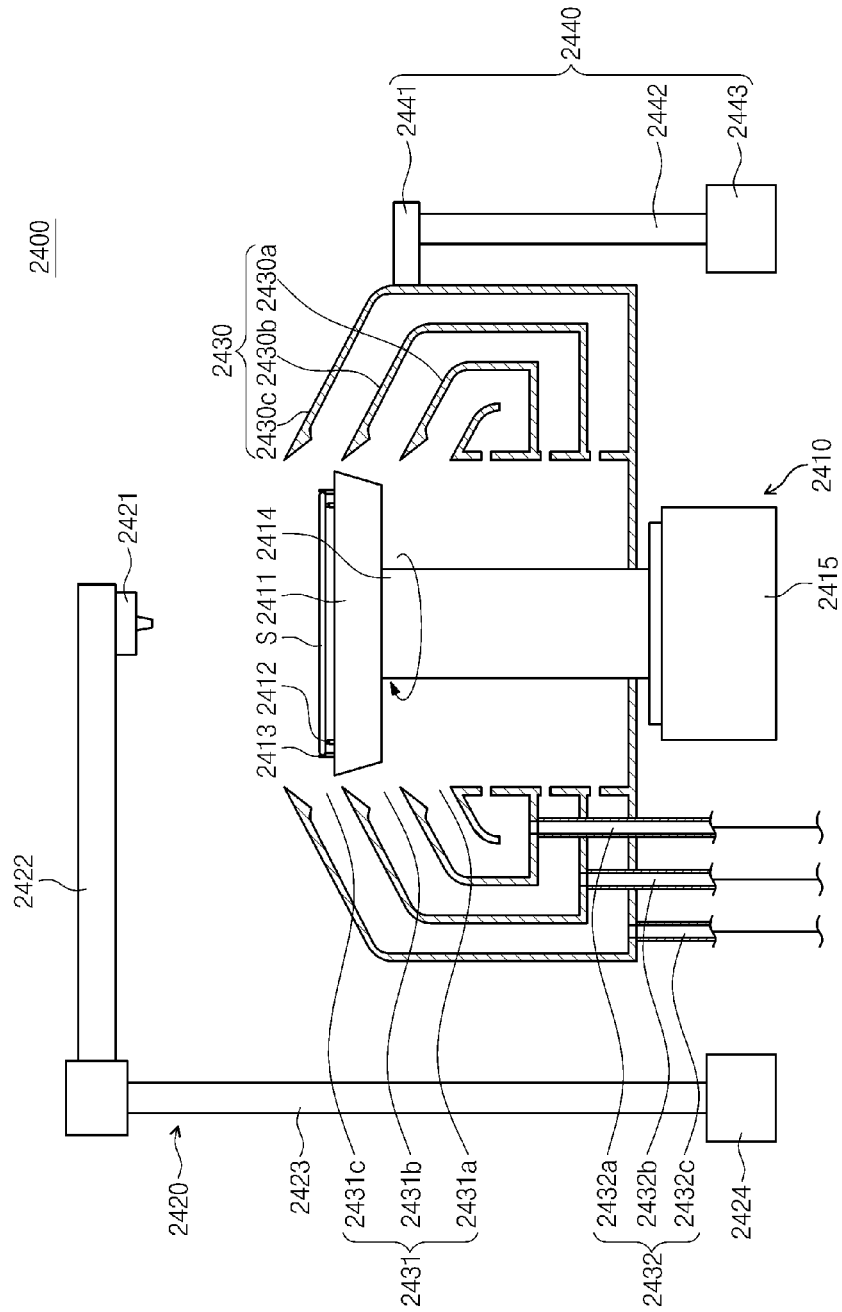


FIG. 3

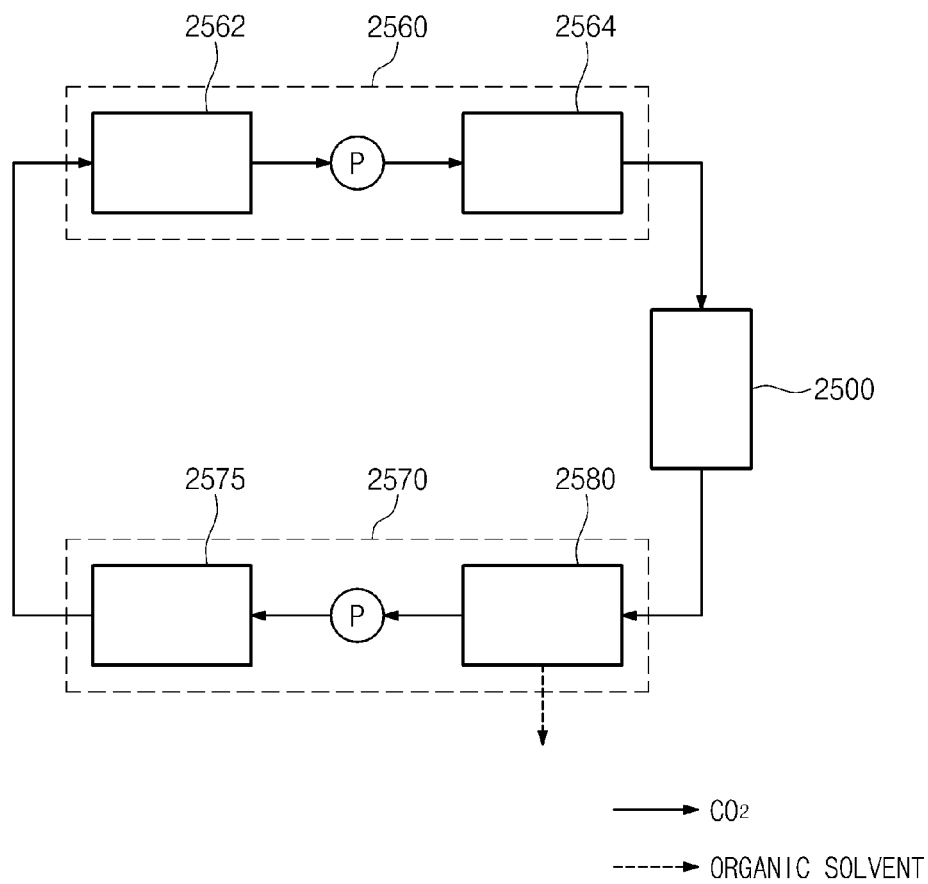


FIG. 4

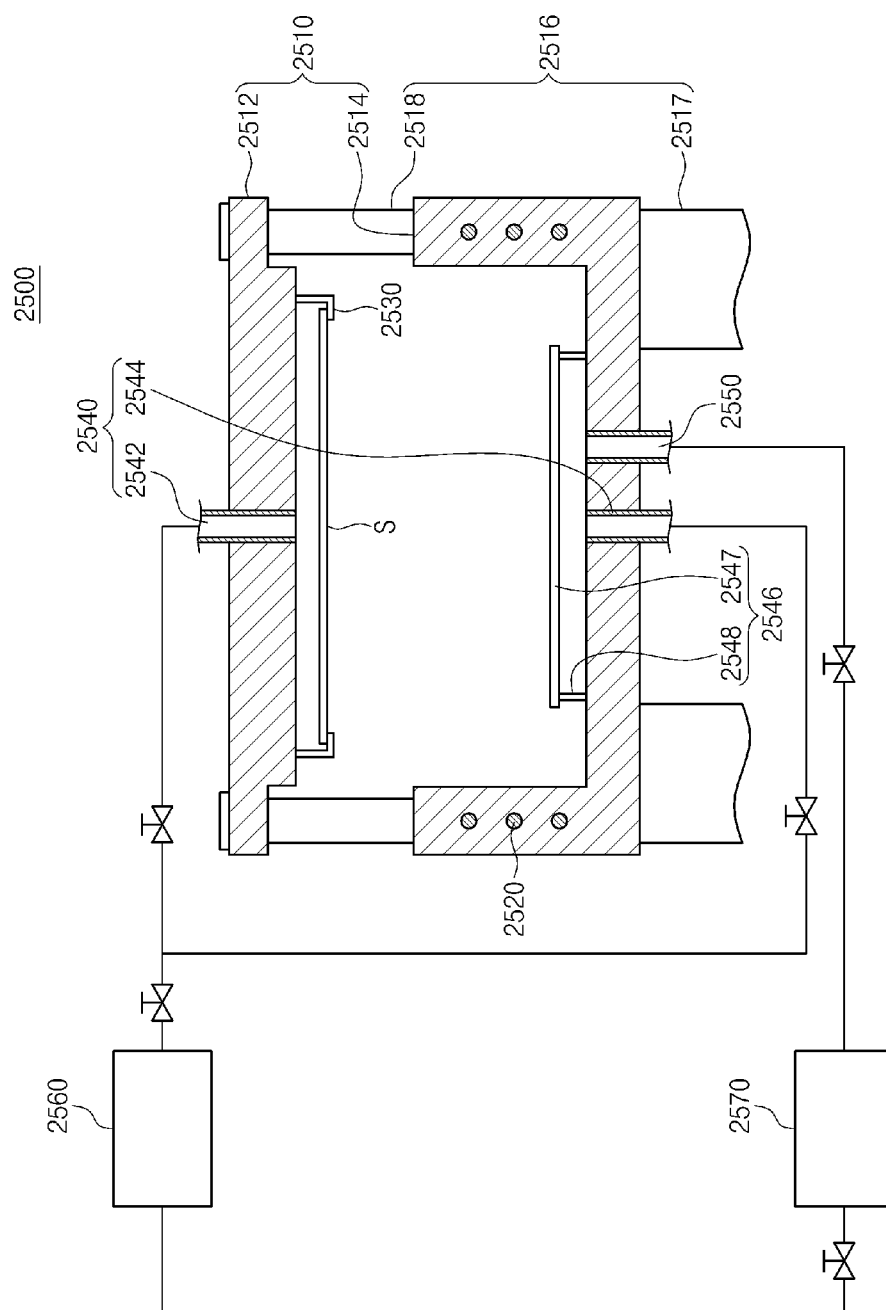


FIG. 5

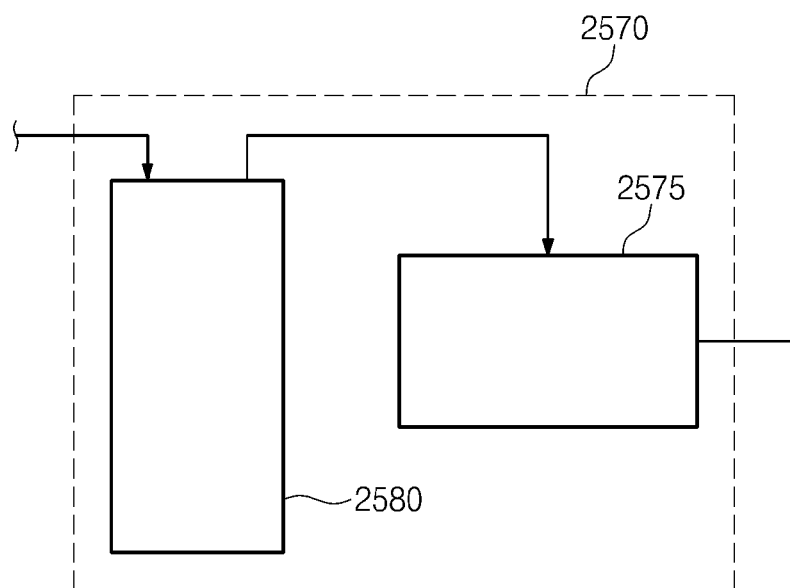


FIG. 6

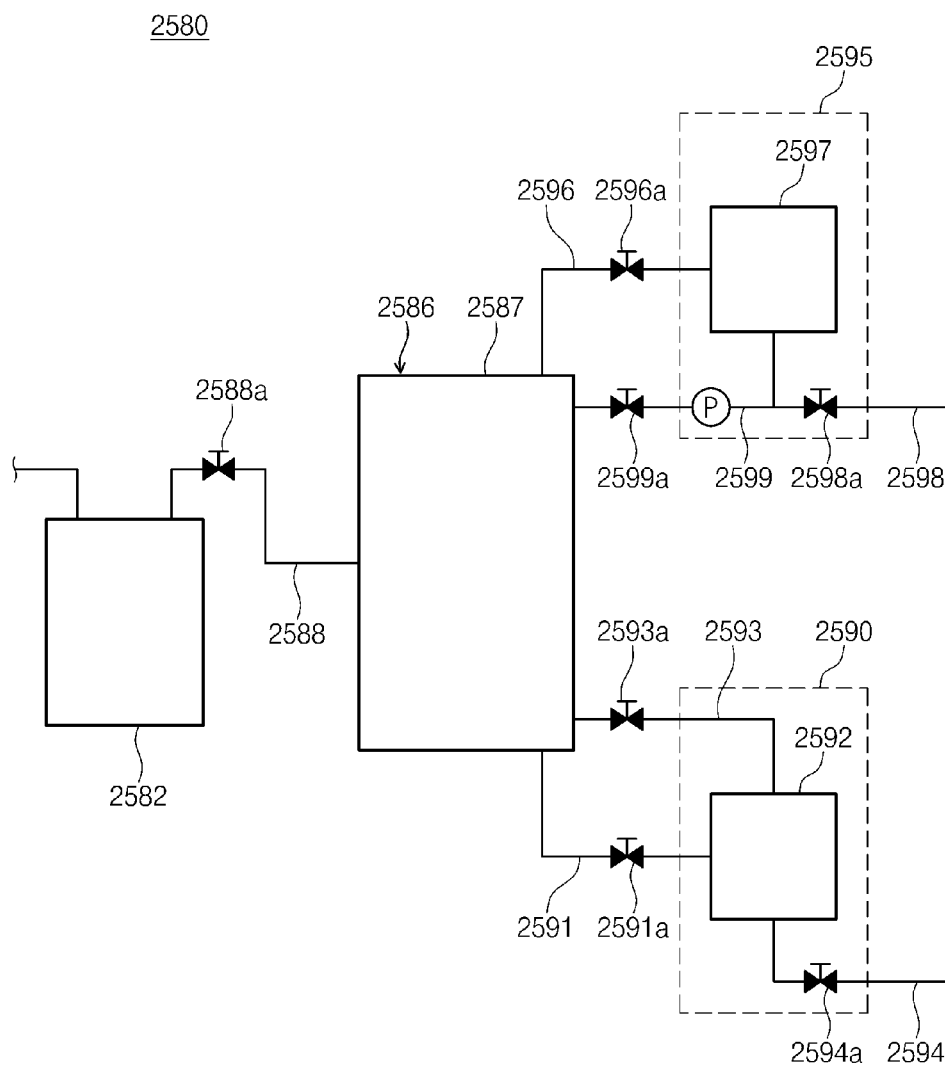


FIG. 7

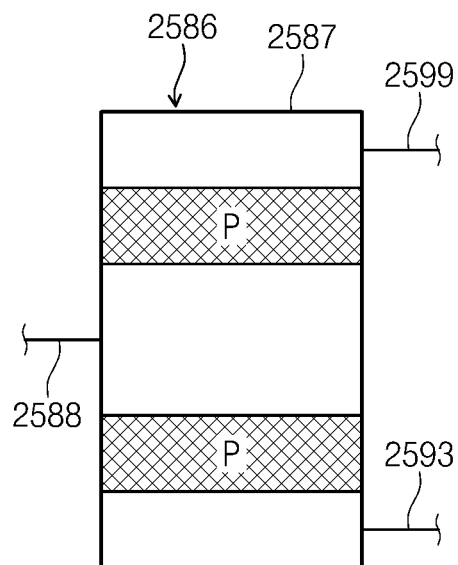


FIG. 8

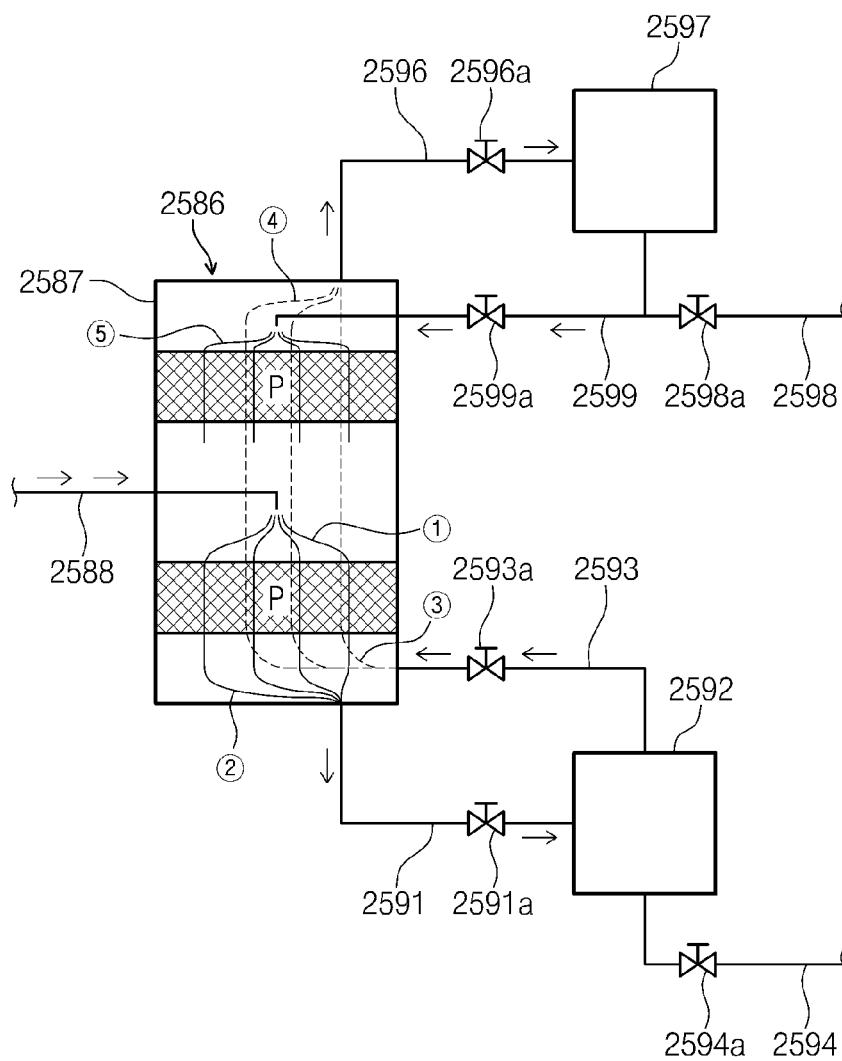


FIG. 9

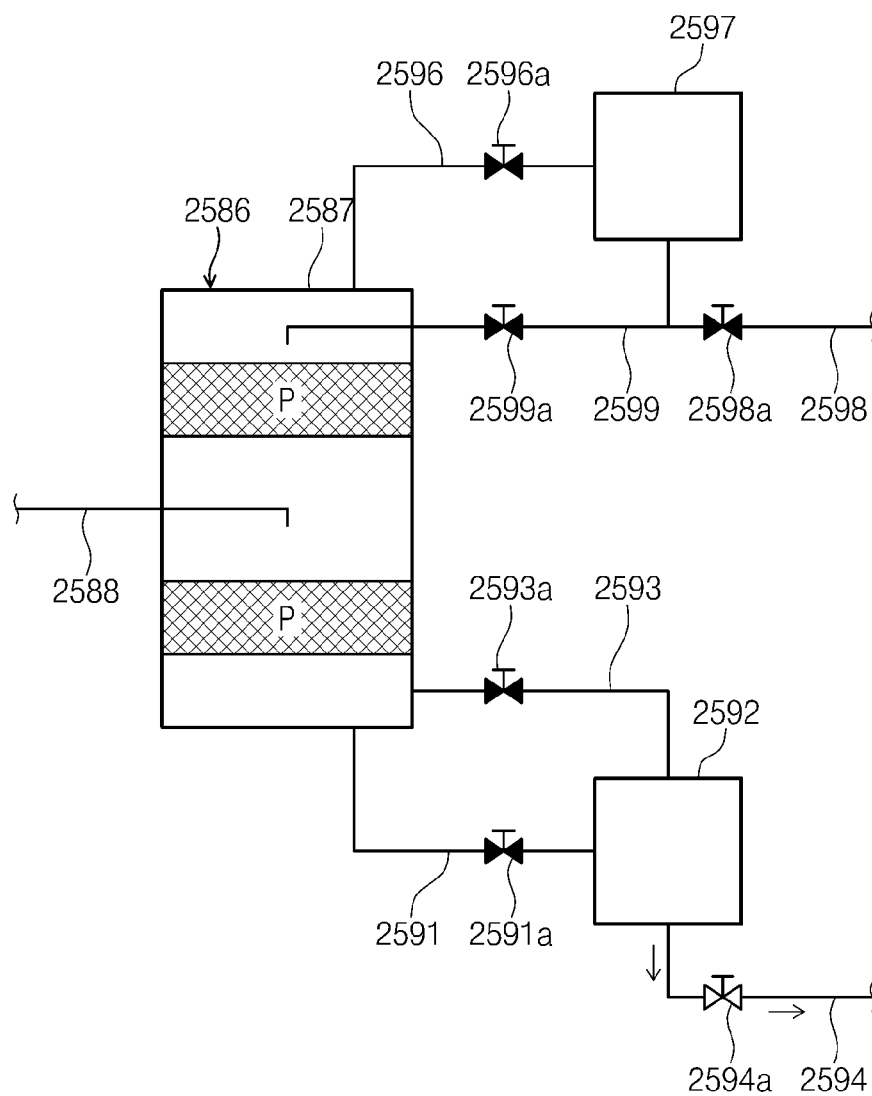


FIG. 10

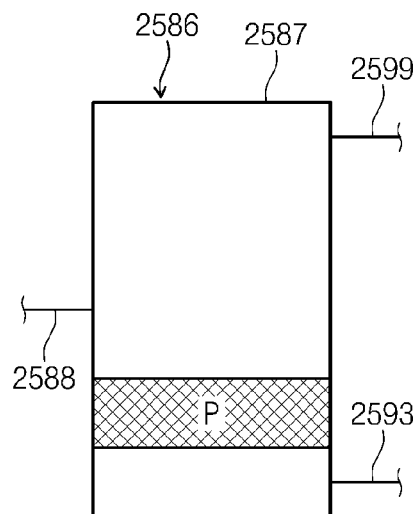


FIG. 11

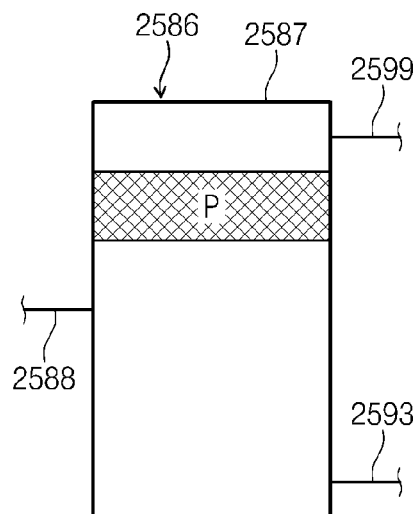


FIG. 12

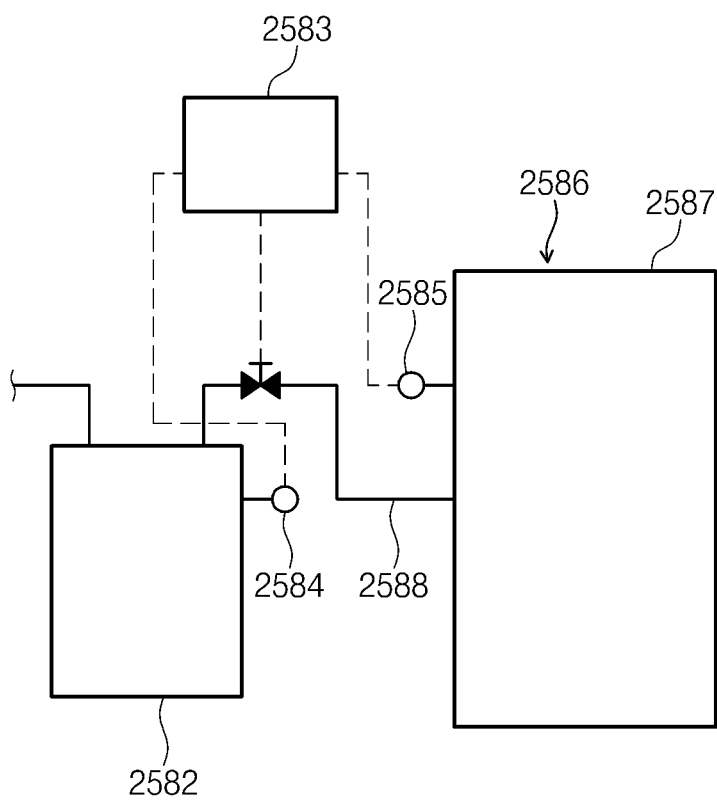


FIG. 13

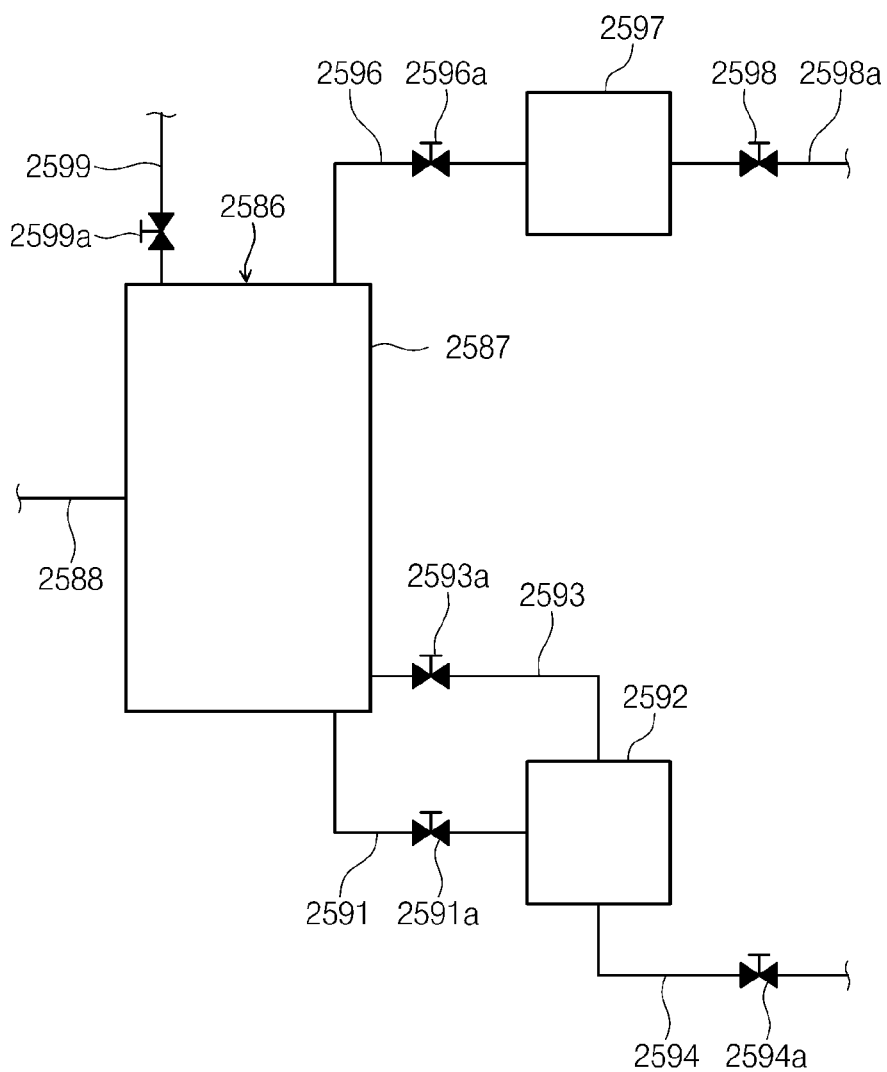


FIG. 14

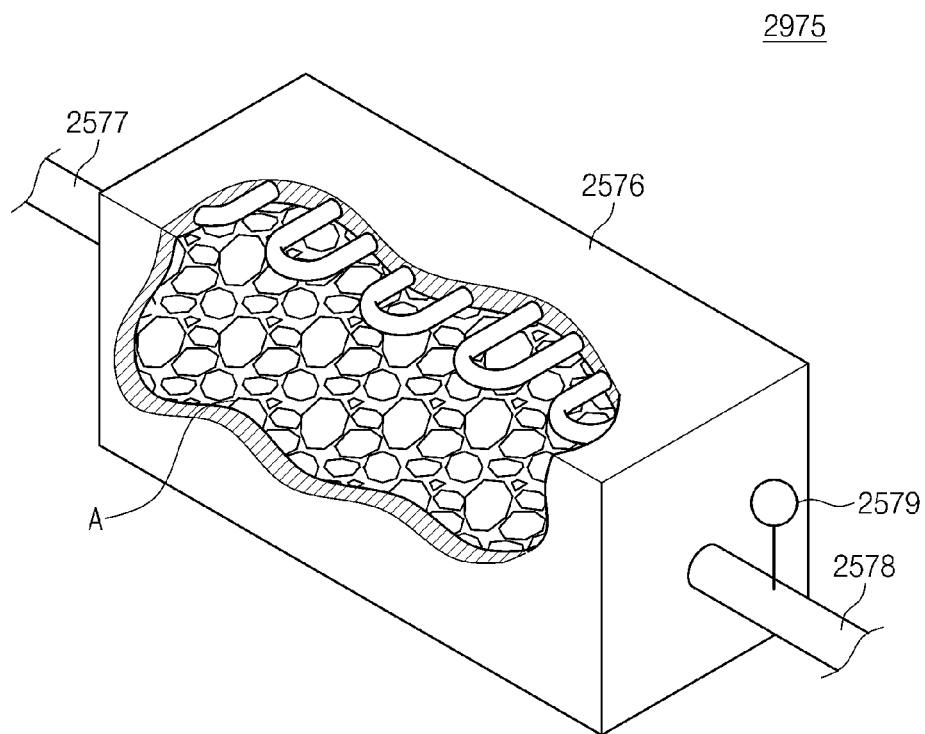


FIG. 15

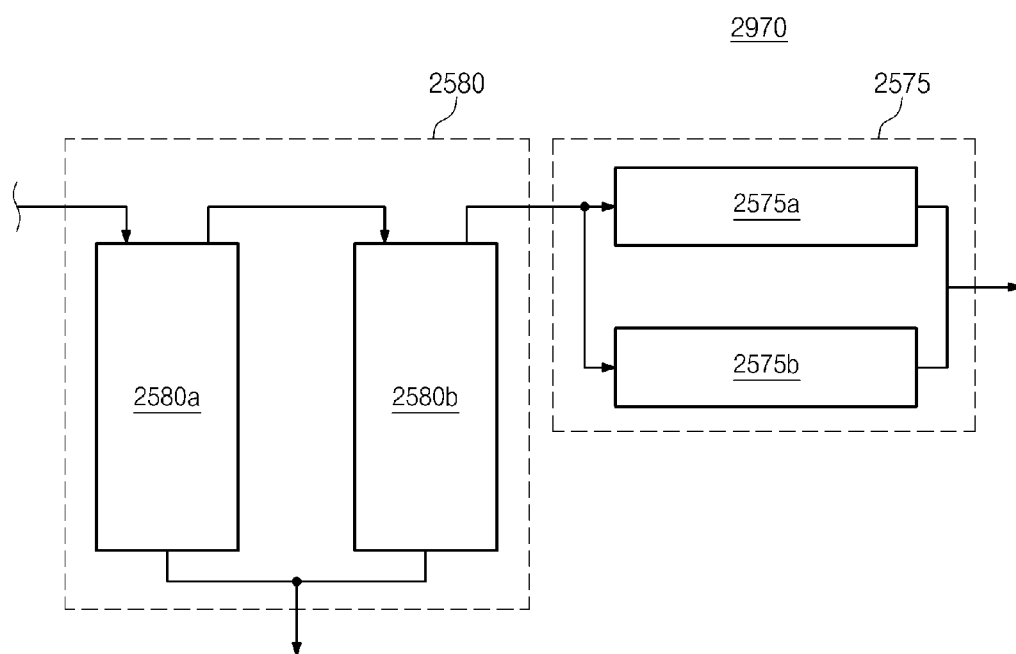
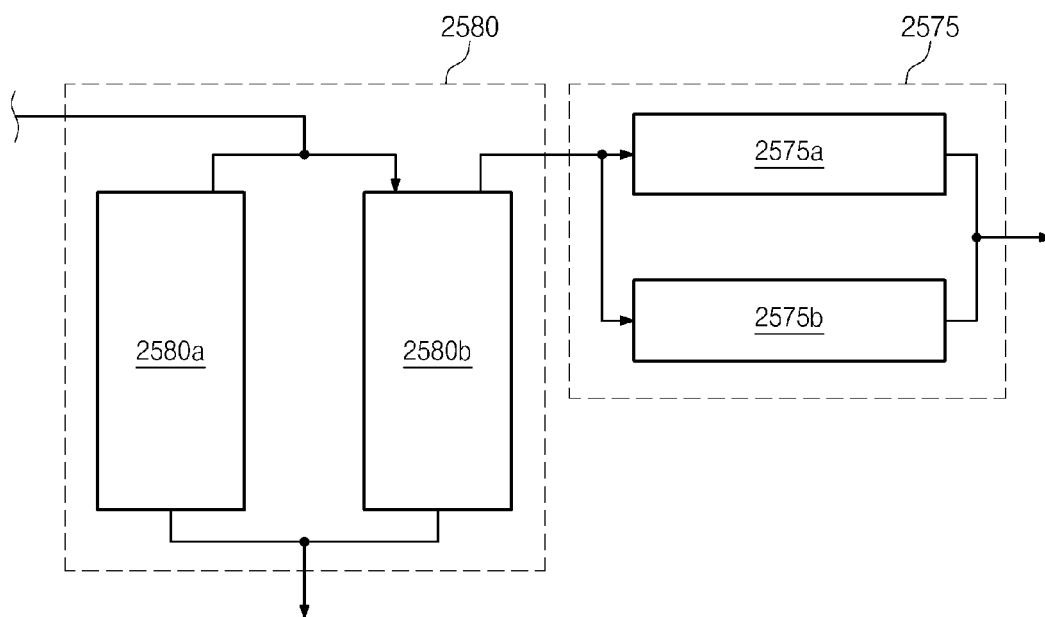


FIG. 16



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RECYCLING UNIT AND SUBSTRATE TREATING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This U.S. non-provisional patent application claims priority under 35 U.S.C. §119 of Korean Patent Application Nos. 10-2013-0034546, filed on Mar. 29, 2013, and 10-2013-0085552, filed on Jul. 19, 2013, the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

The present invention disclosed herein relates to a substrate manufacturing apparatus, and more particularly, to a unit for recycling a supercritical fluid that is used in a supercritical drying process and a substrate treating apparatus including the same.

Semiconductor devices are manufactured through various processes such as a photolithography process for forming a circuit pattern on a substrate such as a silicon wafer. However, during the manufacturing process, various foreign substances such as particles, organic pollutants, metal impurities, and the like may be generated. Since the foreign substances cause substrate defects, this may have a direct effect on yield of the semiconductor devices. Thus, a cleaning process for removing the foreign substances may be essentially involved in the semiconductor manufacturing process.

In a general cleaning process, the foreign substances are removed from a substrate by using a cleansing agent, and then the substrate is cleaned by using deionized water (DI-water). Thereafter, the substrate is dried by using isopropyl alcohol (IPA). However, since the drying process is reduced in drying efficiency when the semiconductor device has a fine circuit pattern, and a pattern collapse phenomenon in which the circuit pattern is damaged during the drying process frequently occurs, the drying process may be unsuitable for a semiconductor device having a line width of about 30 nm or less.

Thus, studies with respect to a technique for drying a substrate by using a supercritical fluid are being actively carried out so as to supplement the above-described drawbacks.

SUMMARY OF THE INVENTION

The present invention provides a substrate treating apparatus that is capable of recovering a high-purity supercritical fluid from a supercritical fluid containing an organic solvent.

The object of the present invention is not limited to the aforesaid, but other objects not described herein will be clearly understood by those skilled in the art from descriptions below.

Embodiments of the present invention provide substrate treating apparatuses including: a drying chamber in which an organic solvent remaining on a substrate is dissolved by using a fluid that is provided as a supercritical fluid to dry the substrate; a supply unit supplying the fluid into the drying chamber; and a recycling unit including a separator for separating the organic solvent from the fluid discharged from the drying chamber to recycle the fluid, the recycling unit supplying the recycled fluid into the supply unit, wherein the separator includes: a distiller in which a fluid containing an organic solvent having a first concentration is introduced; a heating unit heating a fluid containing an organic solvent having a second concentration discharged from the distiller,

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the heating unit supplying an evaporated fluid containing an organic solvent having a third concentration into the distiller; and a condensation unit liquefying a fluid containing an organic solvent having a fourth concentration discharged from the distiller, wherein the organic solvent has the second concentration, the first concentration, the third concentration, and the fourth concentration which are successively lowered in concentration.

In some embodiments, the separator may further include a liquefaction unit disposed between the drying chamber and the distiller to liquefy the fluid discharged from the drying chamber, and the liquefaction unit may supply the fluid containing the organic solvent having the first concentration into the distiller.

In other embodiments, the heating unit may include: a heater; a discharge tube connecting the heater to the distiller to supply the fluid containing the organic solvent having the second concentration from the distiller to the heater; a recovery tube supplying the fluid containing the organic solvent having the third concentration, which is heated by the heater, into the distiller; and an organic solvent discharge tube discharging the organic solvent separated from the fluid containing the organic solvent having the second concentration to the outside of the heater.

In still other embodiments, the distiller may further include: a housing; an inflow tube connecting the liquefaction unit to the housing to supply the fluid containing the organic solvent having the first concentration, which is liquefied by the liquefaction unit, to into the housing, wherein the recovery tube may be connected to the housing at a position that is lower than that of the inflow tube.

In even other embodiments, a lower packing member may be disposed between the recovery tube and the inflow tube in the housing, and the fluid containing the organic solvent having the first concentration and the fluid containing the organic solvent having the third concentration may pass through the lower packing member in directions opposite to each other, respectively.

In yet other embodiments, the condensation unit may include: a condenser; an exhaust tube connecting the distiller to the condenser to supply the fluid containing the organic solvent having the fourth concentration into the condenser; and a fluid discharge tube discharging the fluid liquefied in the condenser into the outside of the condenser.

In further embodiments, the distiller may further include a supply tube supplying a fluid containing an organic solvent having a fifth concentration into an upper portion of the distiller, and the fifth concentration may be less than the third concentration.

In still further embodiments, the supply tube may be branched from the fluid discharge tube, and the fifth concentration may be the same as the fourth concentration.

In even further embodiments, the supply tube may further include a pump supplying the fluid from the condenser to the distiller.

In yet further embodiments, the supply tube may be connected to the housing at a position that is higher than the inflow tube.

In much further embodiments, an upper packing member may be disposed between the inflow tube and the supply tube in the housing, and the fluid containing the organic solvent having the third concentration and the fluid containing the organic solvent having the fifth concentration may pass through the upper packing member in directions opposite to each other, respectively.

In still much further embodiments, the condensation unit may include: a condenser; an exhaust tube connecting the

distiller to the condenser to supply the fluid containing the organic solvent having the fourth concentration into the condenser; and a fluid discharge tube discharging the fluid liquefied in the condenser into the outside of the condenser.

In even much further embodiments, the distiller may include: a housing; an inflow tube supplying the fluid containing the organic solvent having the first concentration, which is liquefied through the liquefaction unit, into the housing; and a supply tube supplying the fluid containing the organic solvent having the fifth concentration into the housing, wherein the supply tube may be connected to the housing at a position that is higher than that of the inflow tube.

In yet much further embodiments, wherein the supply tube may be branched from the fluid discharge tube, and the fifth concentration may be the same as the fourth concentration.

In much still further embodiments, the supply tube may further include a pump supplying the fluid from the condenser to the distiller.

In even still further embodiments, an upper packing member may be disposed between the inflow tube and the supply tube in the housing, and the fluid containing the organic solvent having the third concentration and the fluid containing the organic solvent having the fifth concentration may pass through the upper packing member in directions opposite to each other, respectively.

In yet still further embodiments, the inflow tube may further include: a valve disposed in the inflow tube; a first sensor measuring a pressure within the distiller; a second sensor measuring a pressure within the liquefaction unit; and a controller receiving signals measured by the first and second sensors to control the valve, wherein the controller may close the valve when the pressure within the liquefaction unit is greater than or equal to that within the distiller.

In much even further embodiments, the organic solvent may include isopropyl alcohol (IPA), and the fluid may include carbon dioxide (CO₂).

In other embodiments of the inventive concept, recycling units include: a separator separating an organic solvent from a fluid discharged from a process chamber, wherein the separator includes: a distiller in which a fluid containing an organic solvent having a first concentration is introduced; a heating unit heating a fluid containing an organic solvent having a second concentration discharged from the distiller, the heating unit supplying an evaporated fluid containing an organic solvent having a third concentration into the distiller; and a condensation unit liquefying a fluid containing an organic solvent having a fourth concentration discharged from the distiller, wherein the organic solvent has the second concentration, the first concentration, the third concentration, and the fourth concentration which are successively lowered in concentration.

In some embodiments, the separator may further include a liquefaction unit disposed between the drying chamber and the distiller to liquefy the fluid discharged from the drying chamber, and the liquefaction unit may supply the fluid containing the organic solvent having the first concentration into the distiller.

In other embodiments, the heating unit may include: a heater; a discharge tube connecting the heater to the distiller to supply the fluid containing the organic solvent having the second concentration from the distiller to the heater; a recovery tube supplying the fluid containing the organic solvent having the third concentration, which is heated by the heater, into the distiller; and an organic solvent discharge tube discharging the organic solvent separated from the fluid containing the organic solvent having the second concentration to the outside of the heater.

In still other embodiments, the distiller may further include: a housing; an inflow tube connecting the liquefaction unit to the housing to supply the fluid containing the organic solvent having the first concentration, which is liquefied by the liquefaction unit, to into the housing, wherein the recovery tube may be connected to the housing at a position that is lower than that of the inflow tube.

In even other embodiments, a lower packing member may be disposed between the recovery tube and the inflow tube in the housing, and the fluid containing the organic solvent having the first concentration and the fluid containing the organic solvent having the third concentration may pass through the lower packing member in directions opposite to each other, respectively.

In yet other embodiments, the condensation unit may include: a condenser; an exhaust tube connecting the distiller to the condenser to supply the fluid containing the organic solvent having the fourth concentration into the condenser; and a fluid discharge tube discharging the fluid liquefied in the condenser into the outside of the condenser.

In further embodiments, the distiller may further include a supply tube supplying a fluid containing an organic solvent having a fifth concentration into an upper portion of the distiller, and the fifth concentration may be less than the third concentration.

In still further embodiments, the supply tube may be branched from the fluid discharge tube, and the fifth concentration may be the same as the fourth concentration.

In even further embodiments, the supply tube may be connected to the housing at a position that is higher than the inflow tube.

In yet further embodiments, an upper packing member may be disposed between the inflow tube and the supply tube in the housing, and the fluid containing the organic solvent having the third concentration and the fluid containing the organic solvent having the fifth concentration may pass through the upper packing member in directions opposite to each other, respectively.

In much further embodiments, the condensation unit may include: a condenser; an exhaust tube connecting the distiller to the condenser to supply the fluid containing the organic solvent having the fourth concentration into the condenser; and a fluid discharge tube discharging the fluid liquefied in the condenser into the outside of the condenser.

In still much further embodiments, the distiller may include: a housing; an inflow tube supplying the fluid containing the organic solvent having the first concentration, which is liquefied through the liquefaction unit, into the housing; and a supply tube supplying the fluid containing the organic solvent having the fifth concentration into the housing, wherein the supply tube may be connected to the housing at a position that is higher than that of the inflow tube.

In even much further embodiments, the supply tube may be branched from the fluid discharge tube, and the fifth concentration may be the same as the fourth concentration.

In yet much further embodiments, an upper packing member may be disposed between the inflow tube and the supply tube in the housing, and the fluid containing the organic solvent having the third concentration and the fluid containing the organic solvent having the fifth concentration may pass through the upper packing member in directions opposite to each other, respectively.

In much still further embodiments, the organic solvent may include isopropyl alcohol (IPA), and the fluid may include carbon dioxide (CO₂).

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are included to provide a further understanding of the present invention, and are incor-

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porated in and constitute a part of this specification. The drawings illustrate exemplary embodiments of the present invention and, together with the description, serve to explain principles of the present invention. In the drawings:

FIG. 1 is a plan view of a substrate treating apparatus according to an embodiment;

FIG. 2 is a cross-sectional view of a cleaning chamber of FIG. 1;

FIG. 3 is a view of a circulation system of a supercritical fluid;

FIG. 4 is a cross-sectional view of a drying chamber of FIG. 1 according to an embodiment;

FIG. 5 is a view of a recycling unit of FIG. 3;

FIG. 6 is a view of a separator of FIG. 5;

FIG. 7 is a view illustrating the inside of the separator of FIG. 6;

FIGS. 8 and 9 are views illustrating a recycling process of the separator of FIG. 6;

FIGS. 10 and 11 are views illustrating a modified example of the inside of the separator FIG. 7;

FIG. 12 is a view of a separator according to another embodiment;

FIG. 13 is a view illustrating a modified example of the separator FIG. 5;

FIG. 14 is a view of a recycler of FIG. 5; and

FIGS. 15 and 16 are views illustrating a modified example of the recycling unit of FIG. 5.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the concept of the invention to those skilled in the art. Moreover, it will be understood that although the terms first and second are used herein to describe various elements, these elements should not be limited by these terms. In the following description of the present invention, a detailed description of known functions and configurations incorporated herein will be omitted to avoid making the subject matter of the present invention unclear.

A substrate treating apparatus **100** according to the present invention may be an apparatus for performing a cleaning process on a substrate S.

Here, the substrate S should be construed as sufficiently comprehensive to include all of various wafers such as silicon wafers, glass substrates, organic substrates, and substrates that are used for manufacturing semiconductor devices, displays, and objects in which a circuit is formed on a thin film.

Hereinafter, the substrate treating apparatus **100** will be described according to an embodiment.

FIG. 1 is a plan view of a substrate treating apparatus **100** according to an embodiment.

The substrate treating apparatus **100** includes an index module **1000** and a process module **2000**. The index module **1000** receives a substrate S from the outside to provide the substrate S into the process module **2000**. The process module **2000** performs a cleaning process on the substrate S.

The index module **100** includes an equipment front end module (EFEM), a loadport **1100**, and a transfer frame **1200**. The loadport **1100**, the transfer frame **1200**, and the process module **200** may be successively arranged in a line. Here, a direction in which the loadport **1100**, the transfer frame **1200**, the process module **2000** are arranged may be referred to as a first direction X. Also, a direction perpendicular to the first

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direction X when viewed from an upper side may be referred to as a second direction Y, and a direction perpendicular to the first and second direction X and Y may be referred to as a third direction Z.

At least one loadport **1100** may be provided in the index module **1000**. The loadport **1100** is disposed on a side of the transfer frame **1200**. When the loadport **1100** is provided in plurality, the plurality of loadports **1100** may be arranged in a line along the second direction Y. The number and arrangement of the loadports are not limited to the above-described example. For example, the number and arrangement of the loadports may be adequately controlled in consideration of a foot print and process efficiency of the substrate treating apparatus **100** and a relatively placement of the substrate treating apparatus **100** with respect to the other substrate treating apparatus **100**.

A carrier C in which the substrate S is accommodated is placed on the loadport **1100**. The carrier C is transferred from the outside and then loaded on the loadport **1100**, or is unloaded from the loadport **1100** and then transferred to the outside. For example, the carrier C may be transferred between the substrate treating apparatuses by a transfer device such as an overhead hoist transfer (OHT). Selectively, the transfer of the substrate S may be performed by the other transfer device such as an automatic guided vehicle or a rail guided vehicle instead of the OHT or a worker. A front opening unified pod (FOUP) may be used as the carrier C.

At least one slot for supporting an edge of the substrate S may be defined in the carrier C. When the slot is provided in plurality, the slots may be spaced apart from each other along the third direction Z. For example, the carrier C may accommodate 25 sheets of substrates. The inside of the carrier C may be isolated and sealed from the outside by an openable door. Thus, it may prevent the substrate S accommodated in the carrier C from being contaminated.

The transfer frame **1200** transfers the substrate S between the carrier seated on the loadport **1100** and the process module **2000**. The transfer frame **1200** includes an index robot **1210** and an index rail **1220**.

The index rail **1220** guides a linear movement of the index robot **1210**. The index rail **1220** may have a longitudinal direction that is parallel to the second direction Y.

The index robot **1210** transfers the substrate S. The index robot **1210** may include a base **1211**, a body **1212**, and an arm **1213**.

The base **1211** is disposed on the index rail **1220**. The base **1211** may move along the index rail **1220**. The body **1212** is coupled to the base **1211** to move in the third direction Z or rotate by using the third direction Z as a rotation axis on the base **1211**. The arm **1213** is disposed on the body **1212** to move forward and backward. A hand may be disposed on an end of the arm **1213** to pick up or out the substrate S. At least one arm **1213** may be provided on the index robot **1210**. When the arm **1213** is provided in plurality, the plurality of arms **1213** may be stacked on the body **1212** in the third direction Z. Here, the stacked arms **1213** may be individually driven.

Thus, the base **1211** of the index robot **1210** may move along the index rail **1220** in the second direction Y. As the body **1212** and the arm **1213** operate, the substrate S may be taken out of the carrier C to load the substrate into the process chamber **2000**, or the substrate S may be taken out of the process module **2000** and then accommodated into the carrier C.

On the other hand, the index rail **1220** may not be provided on the transfer frame **1200**. Thus, the index robot **1210** may be fixed to the transfer frame **1200**. Here, the index robot **1210** may be disposed at a center portion of the transfer frame **1200**.

The process module **200** performs the cleaning process on the substrate **S**. The process module **2000** includes a buffer chamber **2100**, a transfer chamber **2200**, a cleaning chamber **2300**, and a drying chamber **2500**. The buffer chamber **2100** and the transfer chamber **2200** are disposed in the first direction **X**, and the transfer chamber **2200** has a longitudinal direction that is parallel to the first direction **X**. The process chambers **2300** and **2500** are disposed on a side surface of the transfer chamber **2200**. The cleaning chamber **2300**, the transfer chamber **2200**, and the drying chamber **2500** may be successively arranged in the second direction **Y**.

The cleaning chamber **2300** may be disposed on one side of the transfer chamber **2200** in the second direction **Y**, and the drying chamber **2500** may be disposed on the other side that is opposite to the cleaning chamber **2300**. The cleaning chamber **2300** may be provided in one or plurality. When the cleaning chamber **2300** is provided in plurality, the cleaning chambers **2300** may be arranged on one side of the transfer chamber **2200** in the first direction **X**, stacked in the third direction **Z**, or disposed by the combination thereof. Similarly, the drying chamber **2500** may be provided in one or plurality. When the drying chamber **2500** is provided in plurality, the drying chambers **2500** may be arranged on the other side of the transfer chamber **2200** in the first direction **X**, stacked in the third direction **Z**, or disposed by the combination thereof.

However, the arrangement of the chambers in the process module **2000** is not limited to the above-described example. For example, the arrangement of the chambers may be adequately modified in consideration of the process efficiency. For example, as necessary, the cleaning chamber **2300** and the drying chamber **2500** may be disposed on the side surface, on which the transfer module is disposed, in the first direction **X** or stacked on each other.

The buffer chamber **2100** is disposed between the transfer frame **1200** and the transfer chamber **2200**. The buffer chamber **2100** provides a buffer space in which the substrate **S** to be transferred between the index module **1000** and the process module **2000** temporarily stays. At least one buffer slot in which the substrate **S** is placed may be provided in the buffer chamber **2100**. When the buffer slot is provided in plurality, the buffer slots may be spaced apart from each other in the third direction **Z**.

The substrate **S** that is taken out of the carrier **C** by the index robot **1210** may be seated on the buffer slot. Also, the substrate **S** that is taken out of the process chambers **2300** and **2500** by the transfer robot **2210** may be seated on the buffer slot. Also, the index robot **1210** or the transfer robot **2210** may take the substrate **S** out of the buffer slot to accommodate the substrate **S** into the carrier **C** or transfer the substrate **S** into the process chambers **2300** and **2500**.

The transfer chamber **2200** transfers the substrate between the buffer chamber **2100**, the cleaning chamber **2300**, and the drying chamber **2500**. The transfer chamber **2200** includes a transfer rail **2220** and a transfer robot **2210**. The transfer rail **2220** provides a path along which the transfer robot **2210** moves. The transfer rail **2220** may be disposed parallel to the first direction **X**. The transfer robot **2210** transfers the substrate **S**. The transfer robot **2210** may include a base **2211**, a body **2212**, and an arm **2213**. Since the components of the transfer robot **2210** are similar to those of the index robot **1210**, their detailed descriptions will be omitted. The transfer robot **2210** may transfer the substrate **S** between the buffer chamber **2100**, the cleaning chamber **2300**, and the drying chamber **2500** by the operations of the body **2212** and the arm **2213** while the base **2211** moves along the transfer rail **2220**.

The cleaning chamber **2300** and the drying chamber **2500** may perform different processes on the substrate **S**. Here, a first process performed in the cleaning chamber **2300** and a second process performed in the drying chamber **2500** may be successively performed. For example, a chemical process, a cleaning process, and a first drying process may be performed in the cleaning chamber **2300**, and a second drying process that is a following process of the first process may be performed in the drying chamber **2500**. Here, the first drying process may be a drying process that is performed by using an organic solvent, and the second drying process may be a supercritical process that is performed by using a supercritical fluid.

Hereinafter, the cleaning chamber **2300** will be described. FIG. **2** is a cross-sectional view of the cleaning chamber **2300** of FIG. **1**.

The first process is performed in the cleaning chamber **2300**. The cleaning chamber **2300** includes a housing **2310** and a process unit **2400**. The housing **2310** defines an outer wall of the cleaning chamber **2300**. The process unit **2400** is disposed inside the housing **2310** to perform the first process.

The process unit **2400** may include a spin head **2410**, a fluid supply member **2420**, a recovery box **2430**, and an elevation member **2440**.

The substrate **S** is seated on the spin head **2410**. The spin head **2410** rotates the substrate **S** while the process is performed. The spin head **2410** may include a support plate **2411**, a support pin **2412**, a chucking pin **2413**, a rotation shaft **2414**, and a motor **2415**.

The support plate **2411** may have an upper portion having a shape similar to that of the substrate **S**. For example, when the substrate includes a circular wafer, the support plate **2411** may have a circular shape. A plurality of support pins **2412** and a plurality of chucking pins **2413** are provided on the support plate **2411**. The substrate **S** is placed on the plurality of support pins **2412**. The plurality of chucking pin **2413** fix the substrate **S**. A rotation shaft **2414** is fixed and coupled to a bottom surface of the support plate **2411**. The rotation shaft **2414** rotates by the motor **2415**. The motor **2415** may generate a rotation force to rotate the support plate **2411** through the rotation shaft **2414**. Thus, the substrate **S** may be seated on the spin head **2410** to rotate the substrate **S** while the first process is performed.

The plurality of support pins **2412** protrude from a top surface of the support plate **2411** in the third direction **Z**. When viewed from an upper side, the support pins **2412** may have an annular ring shape on the whole. A back surface of the substrate **S** is placed on the support pins **2412**. Thus, the substrate **S** may be seated spaced a distance, by which the support pin **2412** protrudes, from the top surface of the support plate **2411** by the support pins **2412**.

The chucking pin **2413** may further protrude from the top surface of the support plate **2411** than the support pin **2412** in the third direction **Z**. The chucking pin **2413** is disposed far away from a center of the support plate **2411** than the support pin **2412**. The chucking pins **2413** may move between a support position and a standby position along a radius direction of the support plate **2411**. The support position may be a position that is spaced a distance that corresponds to a radius of the substrate **S** from the center of the support plate **2411**. The standby position may be a position that is far away from the center of the support plate **2411** when compared to the support position. The chucking pin **2413** may be disposed at the standby position when the substrate **S** is loaded onto or unloaded from the spin head **2410**. Also, the chucking pin **2413** may move to the support position while the process is performed. Thus, the chucking pins **2413** may prevent the

substrate S from being separated in position by a rotation force thereof when the spin head **2410** rotates.

The fluid supply member **2420** supplies a fluid onto the substrate S. The fluid supply member **2420** includes a nozzle **2421**, a support **2422**, a support shaft **2423**, and a driver **2424**. The support shaft **2423** may have a longitudinal direction along the third direction Z. The driver **2424** is coupled to a lower end of the support shaft **2423**. The driver **2424** may rotate the support shaft **2423** or vertically move the support shaft **2423** in the third direction Z. The support **2422** is vertically coupled to an upper portion of the support shaft **2423**. The nozzle **2421** is disposed on a bottom surface of an end of the support **2422**. The nozzle **2421** may move between the support position and the standby position by the rotation and elevation of the support shaft **2423**. The support position may be a position that is disposed directly above the support plate **2411**. The standby position may be a position that get out of the directly upper side of the support plate **2411**.

At least one fluid supply member **2420** may be provided in the process unit **2400**. When the fluid supply member **2420** is provided in plurality, the fluid supply member **2420** may supply fluids different from each other. For example, each of the plurality of fluid supply members **2420** may supply a cleaning agent, a rinsing agent, or an organic solvent. The cleaning agent may include hydrogen peroxide (H_2O_2), ammonia (NH_4OH), hydrogen peroxide (H_2SO_4), hydrofluoric acid (HF), or a mixture thereof. The rinsing agent may include deionized water (DI-water), and the organic solvent may include isopropyl alcohol. Selectively, the organic solvent may include ethyl glycol, 1-propanol, tetra hydraulic franc, 4-hydroxyl, 4-methyl, 2-pentanone, 1-butanol, 2-butanol, methanol, ethanol, n-propyl alcohol, or dimethylether. For example, the first fluid supply member **2420a** may spray an ammonia-hydrogen peroxide solution, the second fluid supply member **2420b** may spray the DI-water, and the third fluid supply member **2420c** may spray an isopropyl alcohol solution. However, the organic solvent may not be provided in a liquid state, but provided in a gaseous state. When the organic solvent is provided as vapor having the gaseous state, the organic solvent may be mixed with an inert gas.

The above-described fluid supply member **2420** may move from the standby position to the support position when the substrate S is seated on the spin head **2410** to supply the above-described fluid onto the substrate S. For example, as the fluid supply member supplies the cleaning agent, the rinsing agent, and the organic solvent, the chemical process, the cleaning process, and the first drying process may be performed. While the above-described processes are performed, the spin head **2410** may rotate to uniformly supply the fluids onto the substrate S.

The recovery box **2430** provides a space in which the first process is performed and recovers the fluid that is used in this process. When viewed from an upper side, the recovery box **2430** may be disposed around the spin head **2410** to surround the spin head **2410**. Here, the recovery box **2430** may have an opened upper portion. At least one recovery box **2430** may be provided in the process unit **2400**. Hereinafter, a case in which three recovery boxes **2430**, i.e., a first recovery box **2430a**, a second recovery box **2430b**, and a third recovery box **2430c** are provided will be described as an example. However, the number of recovery boxes **2430** may be differently selected according to the number of fluids and conditions of the first process.

Each of the first recovery box **2430a**, the second recovery box **2430b**, and the third recovery box **2430c** may have an annular ring shape that surrounds the spin head **2410**. The first recovery box **2430a**, the second recovery box **2430b**, and the

third recovery box **2430c** may be disposed successively away from a center of the spin head **2410**. The first recovery box **2430a** surrounds the spin head **2410**, the second recovery box **2430b** surrounds the first recovery box **2430a**, and the third recovery box **2430c** surrounds the second recovery box **2430b**.

A first inflow tube **2431a** is provided in the first recovery box **2430a** by an inner space of the first recovery box **2430a**. A second inflow tube **2431b** is provided in the second recovery box **2430b** by a space between the first recovery box **2430a** and the second recovery box **2430b**. A third inflow tube **2431c** is provided in the third recovery box **2430c** by a space between the second recovery box **2430b** and the third recovery box **2430c**. The first inflow tube **2431a**, the second inflow tube **2431b**, and the third inflow tube **2431c** may be successively arranged downward from an upper side along the third direction Z. A recovery line **2432** extending downward along the third direction Z is connected to a bottom surface of each of the recovery boxes **2430a**, **2430b**, and **2430c**. Each of the recovery lines **2432a**, **2432b**, and **2432c** may discharge the fluids recovered by the recovery boxes **2430a**, **2430b**, and **2430c** to supply the fluids into an external fluid recycling system (not shown). The fluid recycling system (not shown) may recycle the recovered fluids to reuse the fluids.

The elevation member **2440** includes a bracket **2441**, an elevation shaft **2442**, and an elevator **2443**. The bracket **2441** is fixed to the recovery box **2430**. The elevation shaft **2442** moving by the elevator **2443** in the third direction Z is fixed and coupled to an end of the bracket **2441**. When the recovery box **2430** is provided in plurality, the bracket **2441** may be coupled to the outermost recovery box **2430**.

The elevation member **2440** moves the recovery box **2430** in the third direction Z. Thus, when the recovery box **2430** is provided in plurality, a relative height of the recovery box **2430** with respect to the spin head **2410** may be changed to selectively adjust a height of the inflow tube **2431** of any one recovery box **2430** so that the inflow tube **2431** is disposed on a horizontal plane of the substrate S that is seated on the spin head **2410**.

Also, the elevation member **2440** may move the recovery box **2430** in the third direction Z while the first process is performed to adjust a height of the inflow tube **2431** of the recovery box **2430** so that the inflow tube **2431** corresponds to the substrate S. Thus, as the substrate S rotates, the fluid bounced off the substrate S may be recovered. For example, when the chemical process that is the first process, the cleaning process using the rinsing agent, and the first drying process using the organic solvent are successively performed, the elevation member **2440** may successively move the first inflow tube **2431a**, the second inflow tube **2431b**, and the third inflow tube **2431c**. Thus, each of the first, second, and third recovery boxes **2430a**, **2430b**, and **2430c** may recover the fluid.

The elevation member **2440** may move the spin head **2410** in the third direction Z instead of the movement of the recovery box **2430**.

A second process is performed in the drying chamber **2500**. Here, the second process may be a second drying process for drying the substrate S by using a supercritical fluid.

Hereinafter, carbon dioxide (CO_2) that is used as the supercritical fluid will be described as an example. However, the present invention is not limited to a kind of supercritical fluid.

FIG. 3 is a schematic view of the substrate treating apparatus. The substrate treating apparatus **100** includes the drying chamber **2500**, a supply unit **2560**, and a recycling unit **2570**.

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FIG. 4 is a cross-sectional view of the drying chamber 2500 of FIG. 1 according to an embodiment. Referring to FIG. 4, the drying chamber 2500 may include a housing 2510, an elevation member 2516, a support member 2530, a heating member 2520, a supply port 2540, a blocking member 2546, and an exhaust port 2550.

The housing 2510 may provide a space in which a supercritical drying process is performed. The housing 2510 may be formed of a material that is capable of enduring a high pressure greater than a critical pressure.

The housing 2510 includes an upper housing 2512 and a lower housing 2514.

The upper housing 2512 is fixed, and the lower housing 2514 may be elevated with respect to the upper housing 2512. When the lower housing 2514 descends and then is spaced from the upper housing 2512, an inner space of the drying chamber 2500 may be opened. Thus, the substrate S may be loaded into or unloaded from the inner space of the drying chamber 2500. Here, the substrate S loaded into the drying chamber 2500 may be in a state in which the organic solvent remains after an organic solvent process is performed in the cleaning chamber 3000. Also, when the lower housing 2514 ascends and then is closely attached to the upper housing 2512, the inner space of the drying chamber 2500 may be sealed, and the supercritical drying process may be performed in the inner space. Unlike the above-described example, the lower housing 2514 may be fixed to the housing 2510, and the upper housing 2512 may be elevated with respect to the lower housing 2514.

The elevation member 2516 elevates the lower housing 2514. The elevation member 2516 may include an elevation cylinder 2517 and an elevation rod 2518. The elevation cylinder 2517 is coupled to the lower housing 2514 to generate a vertical driving force.

The support member 2530 supports the substrate S between the upper housing 2512 and the lower housing 2514. The support member 2530 may be disposed on a bottom surface of the upper housing 2512 to extend directly downward. Also, the support member 2530 may be perpendicularly bent from a lower end of the upper housing 2512 in a horizontal direction. Thus, the support member 2530 may support an edge area of the substrate S. As described above, since the support member 2530 contacts the edge region of the substrate S to support the substrate S, the supercritical drying process may be performed on an entire area of a top surface of the substrate S and most areas of a bottom surface of the substrate S. Here, the top surface of the substrate S may be a pattern surface, and the bottom surface of the substrate S may be a non-pattern surface. Also, since the fixed upper housing 2512 is provided, the support member 2530 may relatively stably support the substrate S while the lower housing 2514 is elevated.

A horizontal adjustment member 2532 may be disposed in the upper housing 2512. The horizontal adjustment member 2532 may adjust horizontality of the upper housing 2512. When the upper housing 2512 is adjusted in horizontality, the substrate S seated on the support member 2530 disposed in the upper housing 2512 may be adjusted in horizontality. When the substrate S is tilted in the supercritical drying process, the organic solvent remaining on the substrate S may flow along a slope to cause a phenomenon in which a specific portion of the substrate S is not dried or overdried, thereby damaging the substrate S. The horizontal adjustment member 2532 may adjust horizontality of the substrate S to prevent the above-described phenomenon from occurring.

The heating member 2520 may heat the inside of the drying chamber 2500. The heating member 2520 may heat the super-

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critical fluid supplied into the drying chamber 2500 at a temperature greater than a critical temperature to maintain the supercritical fluid to a supercritical fluid state or change the supercritical fluid again into the supercritical fluid state if the supercritical fluid is liquefied. The heating member 2520 may be buried in at least one wall of the upper and lower housings 2512 and 2514. For example, the heating member 2520 may be provided as a heater for receiving a power from the outside to generate heat.

The supply port 2540 supplies the supercritical fluid to the drying chamber 2500. The supply port 2540 may be connected to the supply unit 2560. A valve for adjusting a flow rate of the supercritical fluid supplied from the supply unit 2560 may be disposed in the supply port 2540.

The supply port 2540 may include an upper supply port 2542 and a lower supply port 2544. The upper supply port 2542 may be provided in the upper housing 2512 to supply the supercritical fluid onto the top surface of the substrate S. The lower supply port 2544 may be provided in the lower housing 2514 to supply the supercritical fluid onto the bottom surface of the substrate S that is supported by the support member 2530.

The supply ports 2540 may spray the supercritical fluid onto a central area of the substrate S. The upper supply port 2542 may be disposed at a position that faces a center of the top surface of the substrate S supported by the support member 2530. Also, the lower supply port 2544 may be disposed at a position that faces a center of the bottom surface of the substrate S supported by the support member 2530.

The supercritical fluid may be supplied first into the housing 4510 through the lower supply port 2544 and then supplied into the housing 2510 through the upper supply port 2542. Since the supercritical drying process is performed in a state where an internal pressure of the drying chamber 2500 is less than the critical pressure, the supercritical fluid supplied into the drying chamber 2500 may be in a liquefied state. Thus, when the supercritical fluid is supplied into the upper supply port 2542 during an initial supercritical drying process, the supercritical fluid may be liquefied to drop onto the substrate S by gravity, thereby damaging the substrate S. The upper supply port 2542 may start the supply of the supercritical fluid, when the supercritical fluid is supplied into the drying chamber 2500 through the lower supply port 2544 to allow the internal pressure of the drying chamber 2500 to reach the supercritical pressure, to liquefy the supercritical fluid, thereby preventing the supercritical fluid from dropping onto the substrate S.

The blocking member 2546 may include a blocking plate 2547 and a support 2548. The blocking plate 2547 is disposed between the supply port 2540 and the substrate S supported by the support member 2530. The blocking plate 2547 may prevent the supercritical fluid supplied through the lower supply port 2544 from being directly sprayed onto the bottom surface of the substrate S. Thus, the blocking plate 2547 may block the direct spraying of the supercritical fluid onto the substrate S to prevent the substrate from being damaged by a physical force of the supercritical fluid. The blocking plate 2547 may have a radius similar to or greater than that of the substrate S. Selectively, the blocking plate 2547 may have a radius less than that of the substrate S. The support 2548 supports the blocking plate 2547. The blocking plate 2547 may be disposed on an end of the support 2548. The support 2548 may extend directly upward from the bottom surface of the housing 2510.

After the process is performed, the supercritical fluid may be exhausted into the recycling unit 2570 through the exhaust port 2550.

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The second drying process is performed in the drying chamber 2500 by using the supercritical fluid. For example, the second drying process may be performed on the substrate S, on which the chemical process, the cleaning process, and the first drying process using the organic solvent are successively performed in the cleaning chamber 2300, by using the supercritical fluid in the drying chamber 2500. When the substrate S is seated on the support member 2530 by the transfer robot 2210, the heating member 2520 heats the inside of the housing 2510 to supply the supercritical fluid through the supercritical fluid supply tube 2540. As a result, a supercritical atmosphere may be formed in the housing 2510. When the supercritical atmosphere is formed, the organic solvent remaining on a top surface of the pattern of the substrate S may be dissolved by the supercritical fluid. When the organic solvent is sufficiently dissolved, the supercritical fluid may be discharged through a discharge hole. Thereafter, the supercritical fluid is supplied again into the supply unit 2560. That is, the supply unit 2560 supplies the supercritical fluid into the drying chamber 2500, and the recycling unit 2570 recycles the supercritical fluid that is used in the drying chamber to supply the recycled supercritical fluid into the supply unit 2560.

Referring again to FIG. 3, the supply unit 2560 may include a condenser 2562, a pump P, and a water supply tank 2564. The condenser 2562, the pump P, and the water supply tank 2564 may be successively connected to each other in series.

The carbon dioxide supplied from the outside or the recycling unit 2570 may be a gaseous state. The condenser 2562 may change the carbon dioxide into a liquid state to supply the liquefied carbon dioxide into the water supply tank 2564. The pump P may be disposed between the condenser 2562 and the water supply tank 2564. The pump P supplies the liquefied carbon dioxide into the water supply tank 2564. The water supply tank 2562 receives the carbon dioxide liquefied in the condenser 2562 to generate the supercritical fluid. The water supply tank 2564 may heat the supplied carbon dioxide to a temperature greater than the critical temperature to generate the supercritical fluid, thereby supplying the supercritical fluid into the drying chamber 2500. Here, the carbon dioxide discharged from the water supply tank 2564 may have a pressed pressure of about 100 bar to about 150 bar.

FIG. 5 is a cross-sectional view of the drying chamber 2570 of FIG. 4 according to an embodiment.

The recycling unit 2570 includes a separator 2580 and a recycler 2575. The recycling unit 2570 may recycle the supercritical fluid, which is used for the second drying process in the drying chamber 2500 containing the organic solvent, to supply the supercritical fluid into the supply unit 2560. The separator 2580 may cool the carbon dioxide to liquefy the organic solvent contained in the carbon dioxide, thereby primarily separating the organic solvent from the carbon dioxide. The recycler 2590 may allow the carbon dioxide to pass through a space in which an absorbent A for absorbing the organic solvent is provided, thereby secondarily separating the organic solvent from the carbon dioxide.

FIG. 6 is a view of the separator 2580 of FIG. 5. FIG. 7 is a cross-sectional of the separator 2580 of FIG. 5. The separator 2580 includes a liquefaction unit 2582, a distiller 2586, a heating unit 2590, and a condensation unit 2595.

The liquefaction unit 2582 is disposed between the drying chamber 2500 and the distiller 2586. The liquefaction unit 2582 liquefies the carbon dioxide. The carbon dioxide discharged from the drying chamber 2500 is supplied into the liquefaction unit 2582 through an inflow tube 2583. The liquefaction unit 2582 supplies the carbon dioxide into the

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distiller 2586. Also, the liquefaction unit 2582 continuously supplies a predetermined amount of carbon dioxide into the distiller 2586.

The distiller 2586 includes a housing 2587 and an inflow tube 2588. The housing 2587 provides a space in which the carbon dioxide containing the organic solvent is fractionally distilled. The inflow tube 2588 connects the liquefaction unit 2582 to the distiller 2586. The carbon dioxide liquefied in the liquefaction unit 2582 is introduced into the distiller 2586 through the inflow tube 2588. The carbon dioxides may be heat-exchanged with each other in the housing 2587. A packing member P is provided inside the housing 2587. The carbon dioxide may pass through the packing member P and thus be spread into an entire region. Thus, the heat-exchange of the carbon dioxide may be occurred in a wider region. Also, since the carbon dioxide is reduced in speed while passing through the packing member P, the heat exchange may be realized over a wider region. Referring to FIG. 7, a recovery tube 2593 is connected to the housing 2587 at a height that is lower than that of the inflow tube 2588. Here, a lower packing member P may be disposed between the inflow tube 2588 and the recovery tube 2593. Referring to FIG. 7, a supply tube 2599 is connected to the housing 2587 at a height that is higher than that of the inflow tube 2588. An upper packing member P may be provided between the supply tube 2593 and the inflow tube 2588. A valve 2588a is disposed in the inflow tube 2588.

The heating unit 2590 includes a discharge tube 2591, a heater 2592, a recovery tube 2593, and an organic solvent discharge tube 2594. The discharge tube 2591 connects the heater 2592 to the distiller 2586. The discharge tube 2591 supplies the carbon dioxide discharged from the distiller 2586 to the heater 2592. The heater 2592 heats the carbon dioxide. The recovery tube 2593 connects the heater 2592 to the distiller 2586. The carbon dioxide that is heated in the heater 2592 and then evaporated is supplied again into the distiller 2586 through the recovery tube 2593. The separated organic solvent is discharged to the outside of the heater 2592 through the organic solvent discharge tube 2594. Valves 2591a, 2593a, and 2594a are disposed in the discharge tube 2591, the recovery tube 2593, and the organic solvent discharge tube 2594, respectively.

The condensation unit 2595 includes an exhaust tube 2596, a condenser 2597, a fluid discharge tube 2598, and a supply tube 2599. The exhaust tube 2596 connects the condenser 2597 to the distiller 2586. The supply tube 2599 connects the condenser 2597 to the distiller 2586. The carbon dioxide fractionally distilled in the distiller 2586 is supplied into the condenser 2597 through the exhaust tube 2596. The gaseous carbon dioxide is condensed in the condenser 2597. Referring to FIG. 6, the supply tube 2599 may be branched from the fluid discharge tube 2598. A portion of the carbon dioxide condensed in the condenser 2597 is supplied into the recycler 2575 through the fluid discharge tube 2598. The other portion of the carbon dioxide condensed in the condenser 2597 is supplied again into the distiller 2586 through the supply tube 2599. Here, the supply tube 2599 may further include a pump P for supplying the carbon dioxide from the condenser 2597 to the distiller 2586. Valves 2596a, 2598a, and 2599a are disposed in the exhaust tube 2596, the fluid discharge tube 2598, and the supply tube 2599.

FIGS. 8 and 9 are views illustrating a process in which the carbon dioxide containing the organic solvent is recycled by using the separator. An arrow represents a flow of the fluid. A valve of which the inside is filled represents a closed valve, and a valve of which the inside is empty represents an opened valve. First, carbon dioxide (see reference numeral ① of FIG. 8) is introduced into the distiller 2586 through the inflow

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tube **2588**. Here, the carbon dioxide contains an organic solvent having a first concentration. The carbon dioxide containing the organic solvent having the first concentration, which is flowed in through the inflow tube **2588** is spread and supplied through the lower packing member P. While the carbon dioxide containing the organic solvent having the first concentration passes through the lower packing member P, the carbon dioxide is heat-exchanged with carbon dioxide (see reference numeral **③** of FIG. **8**) containing an organic solvent having a third concentration, which is supplied through the recovery tube **2593** to reversely pass through the lower packing member P. Here, a portion of the carbon dioxide containing the organic solvent having the first concentration is evaporated. Thus, a portion of the organic solvent may be separated, and then, a carbon dioxide (see reference numeral **②** of FIG. **8**) containing an organic solvent having a second concentration is supplied into a lower portion of the lower packing member P. Here, the second concentration is greater than the first concentration. The carbon dioxide containing the organic solvent having the second concentration is supplied into the heater **2592** through the discharge tube **2591**. The carbon dioxide containing the organic solvent having the second concentration is heated in the heater **2592** at a temperature that is greater than a boiling point of the carbon dioxide and less than a boiling point of the organic solvent. Thus, the carbon dioxide is evaporated in the heater **2592**. Thus, the carbon dioxide containing the organic solvent having the third concentration is generated. The carbon dioxide containing the organic solvent having the third concentration is supplied again into the distiller **2586** through the recovery tube **2593**. The carbon dioxide (see reference numeral **③** of FIG. **8**) containing the organic solvent having the third concentration meets the carbon dioxide containing the organic solvent having the first concentration within the distiller **2586**. In this process, the liquefied carbon dioxide (see reference numeral **①** of FIG. **8**) containing the organic solvent having the first concentration is heat-exchanged with the evaporated carbon dioxide (see reference numeral **③** of FIG. **8**) containing the organic solvent having the third concentration to evaporate a portion of the carbon dioxide containing the organic solvent having the first concentration. Thus, the carbon dioxide containing the organic solvent having the third concentration, which passes through the lower packing member P, is supplied into the upper packing package P. Here, the carbon dioxide passing through the lower packing member P may be provided at a concentration that is lower than the third concentration. The carbon dioxide containing the organic solvent having the third concentration, which is supplied into the upper packing member P meets a carbon dioxide (see reference numeral **⑤** of FIG. **8**) containing an organic solvent having a fourth concentration, which is supplied into the supply tube **2599**. Thus, the carbon dioxide containing the organic solvent having the third concentration and carbon dioxide containing an organic solvent having a fourth concentration are heat-exchanged while reversely passing through the upper packing member P. Since the carbon dioxide containing the organic solvent having the fourth concentration is in a liquid state, a portion of the organic solvent contained in the carbon dioxide containing the organic solvent having the third concentration is liquefied and separated. Thus, the carbon dioxide (see reference numeral **④** of FIG. **8**) containing the organic solvent having the fourth concentration is supplied into the exhaust tube **2596** disposed above the distiller **2586**. The carbon dioxide containing the organic solvent having the fourth concentration is supplied into the condenser **2597** and condensed. A portion of the carbon dioxide containing the organic solvent having the fourth concen-

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tration, which is liquefied in the condenser **2597** is supplied into the recycler **2575** through the fluid discharge tube **2598**. A remaining portion (see reference numeral **⑤** of FIG. **8**) of the carbon dioxide containing the organic solvent having the fourth concentration may be supplied again into the distiller **2586** through the supply tube **2599**. In this process, the organic solvent may have the second concentration, the first concentration, the third concentration, and the fourth concentration, which are successively lowered in concentration. When the organic solvent separation process is finished, as shown in FIG. **9**, the organic solvent is discharged to the outside of the heater **2592** through the organic solvent discharge tube **2594**.

Although the packing member P is disposed on each of the upper and lower portions of the distiller **2586** in the current embodiment, the present invention is not limited thereto. For example, the packing member P may be disposed on the lower portion between the inflow tube **2588** and the recovery tube **2593**. Also, as shown in FIG. **11**, the packing member P may be provided on the upper portion between the inflow tube **2588** and the supply tube **2599** (see FIG. **10**). Also, only one of the heating unit **2590** and the condensation unit **2595** may be provided.

Also, referring to FIG. **12**, the inflow tube **2588** may include a valve **2588a**, a first sensor **2584**, a second sensor **2585**, and a controller **2583**. The valve **2588a** is disposed in the inflow tube **2588**. The first sensor measures an internal pressure of the housing **2587**. The second sensor **2585** measures an internal pressure of the liquefaction unit **2582**. The controller receives signals measured by the first and second sensors **2584** and **2585** to control the valve **2588a**. Here, the controller **2583** may compare internal pressures of the liquefaction unit **2582** and the distiller **2586** to each other. As a result, when the internal pressure of the liquefaction unit **2582** is greater than or equal to that of the distiller **2586**, the valve **2588a** may be closed to stop the supply of the carbon dioxide.

FIG. **13** is a view illustrating a modified example of the separator **2580**.

Referring to FIG. **13**, the separator **2580** include a liquefaction unit **2582**, a distiller **2586**, a heating unit **2590**, and a condensation unit **2595**. Each of the liquefaction unit **2582**, the distiller **2586**, and the heating unit **2590** of FIG. **13** may have substantially the same as or equal to the liquefaction unit **2582**, the distiller **2586**, and the heating unit **2590** of FIG. **6**. However, a supply tube **2599** is independently provided with respect to the fluid discharge tube **2598**. Here, the supply tube **2599** may supply carbon dioxide containing an organic solvent having a fifth concentration into the distiller **2586**. The fifth concentration is less than the third concentration.

FIG. **14** is a cross-sectional of the recycler **2575** of FIG. **5**. The recycler **2575** may include a column **2576**, an inflow tube **2577**, an exhaust tube **2578**, and a concentration sensor **2579**.

The column **2576** has a space in which an absorbent is provided therein. Referring to FIG. **14**, the absorbent A is provided in the column **2591**. The absorbent A has a plurality of pores to absorb the organic solvent in the pores. For example, zeolite may be used as the absorbent. While the carbon dioxide passes through the column **2576**, the absorbent A absorbs the organic solvent from the carbon dioxide. Thus, the organic solvent contained in the carbon dioxide may be removed to recycle the carbon dioxide. The inflow tube **2577** connects the separator **2580** to the column **2576**. The carbon dioxide is introduced into the column **2576** through the inflow tube **2577**. The carbon dioxide is discharged to the exhaust tube **2578** through the column **2576**. The concentration sensor is disposed in the exhaust tube **2578**. The concentration sensor **2579** may detect a concentration of the organic

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solvent contained in the carbon dioxide that is discharged from the column **2976**. The recycled carbon dioxide is supplied into the supply unit **2560** through the exhaust tube **2578**.

On the other hand, the recycling unit **2570** may include a plurality of separators **2580**. Here, as shown in FIG. **15**, the separators **2580** may be connected to each other in series. A first separator **2580a** primarily separates the carbon dioxide and the organic solvent from each other. Then, a second separator **2580b** is connected to the first separator **2580a** to secondarily separate the carbon dioxide and the organic solvent from each other. Thus, the separation of the organic solvent may be performed several times to obtain more pure carbon dioxide. Also, as shown in FIG. **16**, the separator **2580** may be connected to each other in parallel. Thus, the first and second separators **2580a** and **2580b** may separate the carbon dioxide and the organic solvent from each other at the same time to treat more amount of carbon dioxide. Also, the recycler **2575** may be provided in plurality.

Although the separator **2580** is connected to the recycler **2575** in the recycling unit **2570**, the present invention is not limited thereto. For example, when the recycler **2575** is omitted, the separator **2580** may be directly connected to the supply unit **2560**.

According to the embodiment of the present invention, the high-purity supercritical fluid may be recovered or recycled.

The object of the present invention is not limited to the aforesaid, but other objects not described herein will be clearly understood by those skilled in the art from descriptions below.

The present invention has been described above with reference to the aforementioned embodiments. It is evident, however, that many alternative modifications and variations will be apparent to those having skill in the art in light of the foregoing description. Accordingly, the present invention embraces all such alternative modifications and variations as fall within the spirit and scope of the appended claims. Also, the embodiments set forth therein is not so limitedly, but all or part of the embodiments can be selectively combined so as to derive many variations.

What is claimed is:

1. A substrate treating apparatus comprising:
 - a drying chamber in which an organic solvent remaining on a substrate is dissolved by using a fluid that is provided as a supercritical fluid to dry the substrate;
 - a supply unit supplying the fluid into the drying chamber; and
 - a recycling unit comprising a separator for separating the organic solvent from the fluid discharged from the drying chamber to recycle the fluid, the recycling unit supplying the recycled fluid into the supply unit,
 wherein the separator comprises:
 - a distiller in which a fluid containing an organic solvent having a first concentration is flowed in;
 - a heating unit heating a fluid containing an organic solvent having a second concentration discharged from the distiller, the heating unit supplying an evaporated fluid containing an organic solvent having a third concentration into the distiller; and
 - a condensation unit liquefying a fluid containing an organic solvent having a fourth concentration discharged from the distiller,
 wherein the organic solvent has the second concentration, the first concentration, the third concentration, and the fourth concentration which are successively lowered in concentration.
2. The substrate treating apparatus of claim 1, wherein the separator further comprises a liquefaction unit disposed

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between the drying chamber and the distiller to liquefy the fluid discharged from the drying chamber, and

the liquefaction unit supplies the fluid containing the organic solvent having the first concentration into the distiller.

3. The substrate treating apparatus of claim 2, wherein the heating unit comprises:

- a heater;
- a discharge tube connecting the heater to the distiller to supply the fluid containing the organic solvent having the second concentration from the distiller to the heater;
- a recovery tube supplying the fluid containing the organic solvent having the third concentration, which is heated by the heater, into the distiller; and
- an organic solvent discharge tube discharging the organic solvent separated from the fluid containing the organic solvent having the second concentration to the outside of the heater.

4. The substrate treating apparatus of claim 3, wherein the distiller further comprises:

- a housing;
- an inflow tube connecting the liquefaction unit to the housing to supply the fluid containing the organic solvent having the first concentration, which is liquefied by the liquefaction unit, to into the housing,
- wherein the recovery tube is connected to the housing at a position that is lower than that of the inflow tube.

5. The substrate treating apparatus of claim 4, wherein a lower packing member is disposed between the recovery tube and the inflow tube in the housing, and

- the fluid containing the organic solvent having the first concentration and the fluid containing the organic solvent having the third concentration exchange heat by passing through the lower packing member in opposite directions to each other, respectively.

6. The substrate treating apparatus of claim 3, wherein the condensation unit comprises:

- a condenser;
- an exhaust tube connecting the distiller to the condenser to supply the fluid containing the organic solvent having the fourth concentration into the condenser; and
- a fluid discharge tube discharging the fluid liquefied in the condenser into the outside of the condenser.

7. The substrate treating apparatus of claim 6, wherein the distiller further comprises a supply tube supplying a fluid containing an organic solvent having a fifth concentration into an upper portion of the distiller, and

- the fifth concentration is less than the third concentration.

8. The substrate treating apparatus of claim 7, wherein the supply tube is branched from the fluid discharge tube, and the fifth concentration is the same as the fourth concentration.

9. The substrate treating apparatus of claim 8, wherein the supply tube further comprises a pump supplying the fluid from the condenser to the distiller.

10. The substrate treating apparatus of claim 6, wherein the supply tube is connected to the housing at a position that is higher than that of the inflow tube.

11. The substrate treating apparatus of claim 7, wherein an upper packing member is disposed between the inflow tube and the supply tube in the housing, and

- the fluid containing the organic solvent having the third concentration and the fluid containing the organic solvent having the fifth concentration exchange heat by passing through the upper packing member in opposite directions to each other, respectively.

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12. The substrate treating apparatus of claim 2, wherein the condensation unit comprises:

- a condenser;
- an exhaust tube connecting the distiller to the condenser to supply the fluid containing the organic solvent having the fourth concentration into the condenser; and
- a fluid discharge tube discharging the fluid liquefied in the condenser into the outside of the condenser.

13. The substrate treating apparatus of claim 12, wherein the distiller comprises:

- a housing;
- an inflow tube supplying the fluid containing the organic solvent having the first concentration, which is liquefied through the liquefaction unit, into the housing; and
- a supply tube supplying the fluid containing the organic solvent having the fifth concentration into the housing, wherein the supply tube is connected to the housing at a position that is higher than that of the inflow tube.

14. The substrate treating apparatus of claim 13, wherein the supply tube is branched from the fluid discharge tube, and the fifth concentration is the same as the fourth concentration.

15. The substrate treating apparatus of claim 14, wherein the supply tube further comprises a pump supplying the fluid from the condenser to the distiller.

16. The substrate treating apparatus of claim 13, wherein an upper packing member is disposed between the inflow tube and the supply tube in the housing, and

- the fluid containing the organic solvent having the third concentration and the fluid containing the organic solvent having the fifth concentration exchange heat by passing through the upper packing member in opposite directions to each other, respectively.

17. The substrate treating apparatus of claim 4, wherein the inflow tube further comprises:

- a valve disposed in the inflow tube;
 - a first sensor measuring a pressure within the distiller;
 - a second sensor measuring a pressure within the liquefaction unit; and
 - a controller receiving signals measured by the first and second sensors to control the valve,
- wherein the controller closes the valve when the pressure within the liquefaction unit is greater than or equal to that within the distiller.

18. The substrate treating apparatus of claim 1, wherein the organic solvent comprises isopropyl alcohol (IPA), and the fluid comprises carbon dioxide (CO₂).

19. A recycling unit comprising:

- a separator separating an organic solvent from a fluid discharged from a process chamber,
- wherein the separator comprises:
- a distiller in which a fluid containing an organic solvent having a first concentration is flowed in;
- a heating unit heating a fluid containing an organic solvent having a second concentration discharged from the distiller, the heating unit supplying an evaporated fluid containing an organic solvent having a third concentration into the distiller; and
- a condensation unit liquefying a fluid containing an organic solvent having a fourth concentration discharged from the distiller,

wherein the organic solvent has the second concentration, the first concentration, the third concentration, and the fourth concentration which are successively lowered in concentration.

20. The recycling unit of claim 19, wherein the separator further comprises a liquefaction unit disposed between the

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drying chamber and the distiller to liquefy the fluid discharged from the drying chamber, and

- the liquefaction unit supplies the fluid containing the organic solvent having the first concentration into the distiller.

21. The recycling unit of claim 20, wherein the heating unit comprises:

- a heater;
- a discharge tube connecting the heater to the distiller to supply the fluid containing the organic solvent having the second concentration from the distiller to the heater;
- a recovery tube supplying the fluid containing the organic solvent having the third concentration, which is heated by the heater, into the distiller; and
- an organic solvent discharge tube discharging the organic solvent separated from the fluid containing the organic solvent having the second concentration to the outside of the heater.

22. The recycling unit of claim 21, wherein the distiller further comprises:

- a housing;
- an inflow tube connecting the liquefaction unit to the housing to supply the fluid containing the organic solvent having the first concentration, which is liquefied by the liquefaction unit, to into the housing,
- wherein the recovery tube is connected to the housing at a position that is lower than that of the inflow tube.

23. The recycling unit of claim 22, wherein a lower packing member is disposed between the recovery tube and the inflow tube in the housing, and

- the fluid containing the organic solvent having the first concentration and the fluid containing the organic solvent having the third concentration pass through the lower packing member in directions opposite to each other, respectively.

24. The recycling unit of claim 21, wherein the condensation unit comprises:

- a condenser;
- an exhaust tube connecting the distiller to the condenser to supply the fluid containing the organic solvent having the fourth concentration into the condenser; and
- a fluid discharge tube discharging the fluid liquefied in the condenser into the outside of the condenser.

25. The recycling unit of claim 24, wherein the distiller further comprises a supply tube supplying a fluid containing an organic solvent having a fifth concentration into an upper portion of the distiller, and

- the fifth concentration is less than the third concentration.

26. The recycling unit of claim 25, wherein the supply tube is branched from the fluid discharge tube, and the fifth concentration is the same as the fourth concentration.

27. The recycling unit of claim 25, wherein the supply tube is connected to the housing at a position that is higher than that of the inflow tube.

28. The recycling unit of claim 25, wherein an upper packing member is disposed between the inflow tube and the supply tube in the housing, and

- the fluid containing the organic solvent having the third concentration and the fluid containing the organic solvent having the fifth concentration exchange heat by passing through the upper packing member in opposite directions to each other, respectively.

29. The recycling unit of claim 20, wherein the condensation unit comprises:

- a condenser;

an exhaust tube connecting the distiller to the condenser to supply the fluid containing the organic solvent having the fourth concentration into the condenser; and a fluid discharge tube discharging the fluid liquefied in the condenser into the outside of the condenser.

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30. The recycling unit of claim **29**, wherein the distiller comprises:

a housing;

an inflow tube supplying the fluid containing the organic solvent having the first concentration, which is liquefied through the liquefaction unit, into the housing; and

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a supply tube supplying the fluid containing the organic solvent having the fifth concentration into the housing, wherein the supply tube is connected to the housing at a position that is higher than that of the inflow tube.

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31. The recycling unit of claim **30**, wherein the supply tube is branched from the fluid discharge tube, and the fifth concentration is the same as the fourth concentration.

32. The recycling unit of claim **30**, wherein an upper packing member is disposed between the inflow tube and the supply tube in the housing, and

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the fluid containing the organic solvent having the third concentration and the fluid containing the organic solvent having the fifth concentration exchange heat by passing through the upper packing member in opposite directions to each other, respectively.

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33. The recycling unit of claim **19**, wherein the organic solvent comprises isopropyl alcohol (IPA), and the fluid comprises carbon dioxide (CO₂).

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